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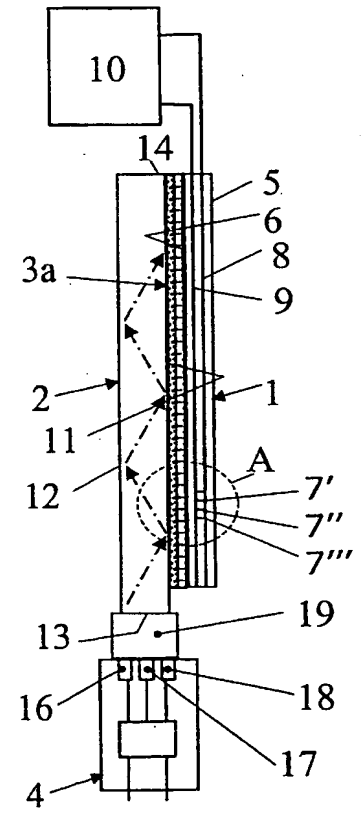
(54) Title: COLOR LIQUID CRYSTAL DISPLAY



(57) Abstract: A system method for the creation of an enhanced brightness and colour LCD display. The display comprises a unitary structure with an LCD panel, Optical waveguide, hologram and light source. During manufacture these elements are bonded together into the unitary structure. The hologram placement varies for the front surface of the optical waveguide, to the back surface of the optical waveguide, on the front and back surface of the optical waveguide at the same time, and disposed within the optical wave guide.

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Title: COLOR LIQUID CRYSTAL DISPLAY

Field of the Invention

1. This invention relates generally to optics and displays. More particularly, the present invention is a system and method that employs holograms as optical elements for the formation of a color image in a Liquid Crystal Display (LCD).

Background of the Invention

2. In general, Liquid Crystal Displays have a front surface, a back surface, and multiple liquid crystal cells disposed between the front and back surfaces. Further, there is usually a means for illumination of a liquid crystal cell from behind the back surface of the entire liquid crystal panel.

3. Illumination sources for liquid crystal panels include optical wave guides which generally comprises a light source which is optically coupled to the optical wave guide and a hologram which is disposed behind the back surface of the LCD panel between the panel and the optical wave guide. This structure is intended to divide incoming white light directed at the hologram into red, green and blue components directed at the liquid crystal cells. A combination of the red, green and blue components give rise to the color image that can then be viewed. Such a structure is illustrated in Patent No. 5,506,701 to Ichikawa, which was issued for a "Hologram Color Filter, Liquid Crystal Display Device Using the Same, and Fabrication Process of Hologram Color Filter."

4. Such a system as described in the >701 Patent still allows certain partially unrefracted light is transmitted through the hologram to the liquid crystal cells, thereby partially degrading the image quality. Further, the >701 Patent relies upon a precise orientation between a mask, a micro lens, corresponding hologram areas, and the liquid crystal cells in order to give rise to the color display. If this orientation is off by a slight amount, the image quality is adversely affected. Therefore the ability to manufacture a display using the technology of the >701 Patent requires a great deal of precision in manufacturing.

5. What would be truly useful is a system and method to create a high-quality color image using simple construction and manufacturing technology on a Liquid Crystal Display.

Summary of the Invention

6. It is therefore an objective of the present invention to employ holograms as optical elements in the formation of a color image in a Liquid Crystal Display.

7. It is a further objective of the present invention to create color Liquid Crystal Displays which are easy to manufacture.

8. It is yet another objective of the present invention to eliminate the need for precise orientation of elements in a color Liquid Crystal Display.

9. It is a further objective of the present invention to enhance the brightness of color images created with Liquid Crystal Displays.

10. These and other objectives of the present invention will become apparent to those skilled in the art by a review of the specification that follows.

11. The present invention is a color Liquid Crystal Display having a front surface, a back surface which is parallel to the front surface, with intervening multiple liquid crystal cells disposed between the front surface and the back surface. A hologram is disposed behind the back surface of the liquid crystal panel and means for illumination of the liquid crystal cells from behind the back surface of the liquid crystal panel is provided.

12. Satisfactory means for illumination of the liquid crystal cells include an optical waveguide also having front and back surfaces which are substantially parallel to the liquid crystal panel. A hologram is incorporated into the optical waveguide. The optical waveguide is coupled to the liquid crystal panel which forms a unitary structure comprising the liquid crystal panel and the optical waveguide.

13. This coupling of the optical waveguide directly to the liquid crystal panel improves the quality of the subsequent color image, including its brightness, sharpness, and color reproduction. This enhancement is due to a decreased emission loss between the light source and the liquid crystal cells and is also due to the decreased chromatic distortions in the division of white light into the color components which illuminate the liquid crystal cells.

14. In addition to the above advantages, direct coupling of the optical waveguide, which also comprises the hologram, allows for a higher degree of precision in the orientation of the hologram with respect to the LCD display elements.

15. The liquid crystal panel of the present invention is also a simpler design. Unlike the '701 Patent, a mask is not required. Thus, the exclusion of at least one other element leads to a simpler construction.

16. With the LCD panel of the present invention, the hologram can be applied to the first surface of the optical waveguide. Alternatively, the hologram can be applied to the second surface of the optical waveguide or to both side surfaces of the optical waveguide. In addition, the hologram may also be inside the optical waveguide equidistant between the first and second sides. All of these alternative placements of the hologram comprise alternative embodiments of the present invention and fulfill the overall objectives of providing a higher quality, higher brightness color Liquid Crystal Display panel.

17. The optical waveguide is coupled to the liquid crystal panel by means of a transparent adhesive which connects the liquid crystal panel and the optical waveguide together in a unitary structure. This provides a higher degree of resistance to various mechanical loads that may be placed upon the display. This adhesive is applied between the optical waveguide and the liquid crystal panel such that the thickness of the adhesive is less than the thickness of the optical waveguide. Further, the adhesive has a refractive index that is lower than that of the optical waveguide material.

18. The light source used with the optical wave guide is formed by red, green and blue emitters. Light emitting diodes in the red, green and blue regions of the spectrum are preferable sources, although this is not meant as a limitation. Other sources of polychromatic light will also be practical for the present invention.

19. Using this design of the present invention, the precision of color rendition is enhanced by the removal of chromatic distortions and through separate control of the intensity of each of the red, green and blue emitters.

Brief Description of the Drawings

Figure 1 illustrates a cross-sectional view of the display of the present invention.

Figure 2 illustrates a magnified view of a section of the display of the present invention.

Figure 3 illustrates the adhesive gap between the LCD display and the waveguide of the present invention.

Figure 4 illustrates an alternative embodiment for the placement of the hologram used with the present invention.

Figure 5 illustrates an alternative embodiment of the present invention with a hologram located within the waveguide.

Figure 6 illustrates an alternate embodiment of the present invention that works with a reflection type LCD.

Detailed Description of the Invention

20. As noted above, the present invention is a Liquid Crystal Display employing holograms to enhance the color and brightness of the image formed in the LCD display.

21. Referring first to Figure 1, a side view of the present invention is illustrated. The invention comprises a Liquid Crystal Display 1 with an associated optical waveguide 2, which is coupled to the Liquid Crystal Display 1. In this illustration, a hologram 3A is positioned on the first side of the optical waveguide 2. Light source 4 comprises, preferable light emitting diodes 16, 17, 18 in the red, green and blue region of the spectrum. As noted above, the use of LEDs is not meant as a limitation since other sources of polychromatic light may also be suitable for the present invention.

22. The light source 4 is coupled to the waveguide 2 through an adapter 19.

23. The liquid crystal panel 1 has a front surface 5 and a back surface 6 which are parallel to one another. Disposed between the front surface and back surface are multiple liquid crystal cells herein illustrated as 7', 7", and 7"'. The liquid crystal cells form a matrix in parallel lines, predominantly at right angles to one another so that a ninety-degree angle matrix is formed between front surface 5 and back surface 6 of the liquid crystal panel 1.

24. Front surface 5 of the liquid crystal panel 1 carries a first row of parallel electrodes 8. These electrodes coincide with the parallel rows of liquid crystal cells 7', 7", and 7"', and run in a first direction.

25. The back surface 6 of the liquid crystal panel 1 carries a second row of parallel electrodes 9 located mainly at right angle to the electrodes 8 in the front surface of the liquid crystal panel. The electrodes in the back surface 6 coincide with the parallel rows of liquid crystal cells 7', 7", and 7"' and run in a second direction crossing the parallel rows of electrodes which run in the first direction on front surface 5. Thus, the electrodes 8 and 9 forming net coinciding with the rows of liquid crystal cells 7', 7", and 7"'. The electrodes 8 and 9 are electrically coupled to the controlling unit 10.

26. Optical waveguide 2 and light source 4 comprise the means for illumination of the liquid crystal cells 7', 7", and 7"' from behind the back surface 6 of the liquid crystal panel 1.

27. Optical waveguide 2 comprises a transparent material with a polished first side surface 11 which is parallel to the back surface 6 of the liquid crystal panel 1. The optical waveguide 2 also comprises a polished second side surface 12 which is parallel to first side surface 11 of the optical waveguide. Second side surface 12 runs parallel to first side surface 11.

28. Between back surface 6 of the liquid crystal panel and the first side surface 11 of the optical waveguide, is a gap which is filled with a transparent material used as an adhesive. This gap is smaller in dimension than the thickness of the optical waveguide. This gap 15 is filled with an adhesive having a refractive index lower than that of the material of which the optical waveguide 2 is constructed. Thus the adhesive connects the liquid crystal panel and the optical waveguide together and couples them together as a unit, thus providing a higher degree of structural stability which resists mechanical loads which may be placed on the display.

29. Light source 4 can be an incandescent lamp or light emitting diodes or other suitable light source having a polychromatic characteristic. The light source is located at the end face 13 of optical waveguide 2. The adapter 19 comprises a transparent material and couples the light source 4 to the endface 13 of optical waveguide 2.

30. Hologram 3A, in the illustration of Figure 1 is disposed behind the back surface of liquid crystal panel 1. As will be more fully explained below, the location of the hologram can vary and, in one embodiment may be on the first surface 11 of the optical waveguide. Alternatively, the hologram can be formed on a portion of the first and second surfaces of the optical waveguide, in the middle of the optical waveguide, or at other locations as will be more fully explained below.

31. In operation, voltage is provided to light source 14 which causes LEDs 16, 17, 18 to emit light in the red, green and blue region of the spectrum respectively. The white light resulting from the combination of red, green and blue lights is transmitted through the adapter 19 into the optical waveguide 2 via the endface of the waveguide 13.

32. The intensity of the light emitted from each LED can be separately controlled by the light source 4. This individual control leads to enhanced precision of the color rendition and removes chromatic distortions of the display image.

33. Light from the light source is totally internally reflected from both side surfaces 11 and 12 of optical waveguide 2. The white light spreads throughout the optical waveguide 2 and becomes defracted via the hologram 3A. The defracted light emerges from optical waveguide 2 through its side surface 11 and toward the liquid crystal cells 7', 7", and 7"' from behind the back surface 6 of the liquid crystal panel. Light which is not defracted via the hologram 3A remains inside the waveguide 2 and, after multiple reflections, impacts other areas of the hologram and becomes defracted. Thereafter, the light again impinges on waveguide 2 in the direction of liquid crystal panel 1.

34. Since hologram 3A is incorporated into the optical waveguide 2 this decreases emission losses thereby more fully utilizing the light power of the optical waveguide through the illumination of the liquid crystal panel. Thus, the panel is more efficient.

35. Hologram 3A is designed such that it forms red, green and blue beams directed at LCD cells 7', 7", and 7"' respectively such that the light of one color impinges on each cell without chromatic distortion. Thus, cell 7' may be, for example red, 7" may be, for example green, and 7"' may be, for example blue.

36. Since liquid crystal panel 1 and optical waveguide 2 are connected together as a unit and since hologram 3A is incorporated into the optical waveguide 2, there is a much higher degree of precision in the orientation and focusing of light beams toward LCD cells 7', 7", and 7"' of the liquid crystal panel 1.

37. Even illumination of all cells is accomplished by the inter-reflections from the internal faces of the optical waveguide 2.

38. As in normal LCD , control unit 10 provides voltage to the electrodes 8 and 9 hence, changing the transparency of LCD cells 7', 7", and 7"'.

39. Thus the different color lights passing through the liquid crystal panel forms high quality color image with enhanced brightness, sharpness, and color reproduction. The display of the present invention can be used for monitors, television receivers, and all manner of devices where screens display information.

40. Referring now to Figure 2, an enlarged section of the panel of the present invention is illustrated. LCD panel 1 comprises front surface 5 and back surface 6. Disposed between the front and back surfaces are the array of liquid crystal cells 7', 7", and 7'". A gap B exists between the LCD panel 1 and the optical waveguide 2. This gap is filled with an adhesive having an index of refraction less than that of optical waveguide 2. Further, this adhesive layer 15 is narrower than the width A of optical waveguide 2.

41. Optical waveguide 2 has a front surface 11 and a back surface 12 both of which are highly polished. Hologram 3A is positioned on the front surface of the optical waveguide.

42. Referring to Figure 3, an alternative embodiment of the present invention is illustrated. Again, LCD panel 1 comprises front surface 5 and back surface 6 and has liquid crystal cells 7', 7", and 7'" disposed between the two surfaces. Gap 15 is filled with an adhesive that couples the optical waveguide 2 to the liquid crystal panel 1. This adhesive layer is of a thickness which is less than the thickness of the optical waveguide. In this illustration however, hologram 3B is disposed on the back surface of optical waveguide 2 and serves to defract the inter-reflections into the respective colors which are then defracted onto the cells of the liquid crystal panel.

43. Referring to Figure 4, yet another alternative embodiment of the present invention is illustrated. In this illustration however, holograms 3C and 3D are disposed on the front and back surfaces of optical waveguide 2. These holograms again defract the light in the separate regions of the spectrum onto the liquid crystal cells of the liquid crystal panel 1.

44. Referring to Figure 5, yet another embodiment of the present invention is illustrated. In this instance, hologram 3F is disposed central to the optical waveguide 2 and equidistant from the front surface 11 and back surface 12 of the optical waveguide. Again, light defracted via the hologram is projected onto liquid crystal panel cells 7', 7", and 7'".

45. Referring to figure 6 the system of the present invention is further illustrated in a reflection LCD embodiment. The liquid crystal panel 1 has a front surface 5 and a back surface 6 which are parallel to one another. Optical waveguide 2 comprises a transparent material with a polished first side surface 11 which is parallel to the back surface 6 of the liquid crystal panel 1. Optical waveguide 2 has a front surface 11 and a back surface 12 both of which are highly polished. Hologram 3A is positioned on the front surface of the optical waveguide. The back surface 6 of the liquid crystal panel 1 carries a second row of parallel electrodes 9 located mainly at right angle to the electrodes 8 in the front surface of the liquid crystal panel. Layer 801 of the reflection LCD depicted in Figure 6 reflects all light, that comes through the LCD active layer 8. This illustration of the construction of a reflection LCD is the normal structure for an active matrix color LCD) Light beams 701, 702, 703 are reflected beams that are reflected through the waveguide 2 that have different colours in the plane of LCD cells - 7',7",7'". The angles of outgoing beams (from the hologram 3a) differs from the beams reflected from reflector 801 so the beams 701, 702, 703 comes through the hologram 3a and substrate 2 with minimum attenuation.

46. A system and method for the creation of a high quality, high brightness color image liquid crystal display has now been illustrated. It will be apparent to those skilled in the art that other variations of the present invention are possible without departing from the scope of the invention as disclosed.

I claim:

1. An enhanced brightness and color display comprising:
    1. A liquid crystal display (LCD) panel;
    2. An optical wave guide having a first index of refraction and first thickness;
    3. A hologram coupled to the optical wave guide;
    4. An adhesive layer between the LCD panel and the optical wave guide adapted for coupling the LCD panel to the optical wave guide;
    5. A light source coupled to the optical wave guide; and
    6. Wherein the LCD panel, the optical wave guide, the hologram and the light source comprise a unitary device.
2. The enhanced brightness and color display of claim 1 wherein the LCD panel further comprises a front surface a rear surface, and a layer of liquid crystals disposed between the front and rear surfaces.
3. The enhanced brightness and color display of claim 1 wherein the optical wave guide comprises a front surface, a rear surface, first and second end faces; and

   Wherein the hologram is coupled to the first optical wave guide face.
4. The enhanced brightness and color display of claim 1 wherein the adhesive layer comprises an adhesive having a second index of refraction less than the first index of refraction.
5. The enhanced brightness and color display of claim 4 wherein the adhesive layer is of a second thickness less than that of the first thickness of the optical wave guide.

6. The enhanced brightness and color display of claim 1 wherein the hologram is coupled to the second optical waveguide surface.

7. The enhanced brightness and color display of claim 1 wherein the hologram is couple to the optical waveguide in the center of the waveguide equidistant from the front and rear surfaces of the optical waveguide.

8. The enhanced brightness and color display of claim 3 wherein the light source is coupled to the first optical wave guide end.

9. The enhanced brightness and color display of claim 8 wherein the light source further comprises a polychromatic light source.

10. The enhanced brightness and color display of claim 9 wherein the polychromatic light source comprises a red light emitting diode (LED), and green LED and a blue LED.

11. The enhanced brightness and color display of claim 10 wherein the red, green, and blue LCD are individually controlled by a light source control.

12. A method of manufacturing an enhanced brightness and color LCD display comprising:

1. Creating a color LCD panel having a front and back surface;
2. Coupling an optical waveguide, having front and back surfaces and first and second end faces, to the back surface of the LCD panel via and adhesive layer;
3. Coupling a hologram onto the optical waveguide;
4. Coupling a light source, having power and a controller, to the first end face of the optical waveguide;
5. Whereby the LCD panel, the hologram, the optical waveguide, and the light source create a unitary display; and

6. Illuminating the LCD panel by applying power to the light source via controller, reflecting the light from the light source within the optical waveguide; diffracting the light into color components by action of the hologram, and illuminating individual liquid crystal elements of the LCD display with the diffracted light from the hologram.

13. The method of manufacturing an enhanced brightness and color LCD display of claim 12 wherein the light source is a polychromatic light source.

14. The method of manufacturing an enhanced brightness and color LCD display of claim 13 wherein the polychromatic light source comprises a red LED, a green :ED and a blue LED.

15. The method of manufacturing an enhanced brightness and color LCD display of claim 14 further comprising the controller controlling the power individually to the red, green and blue LEDs.

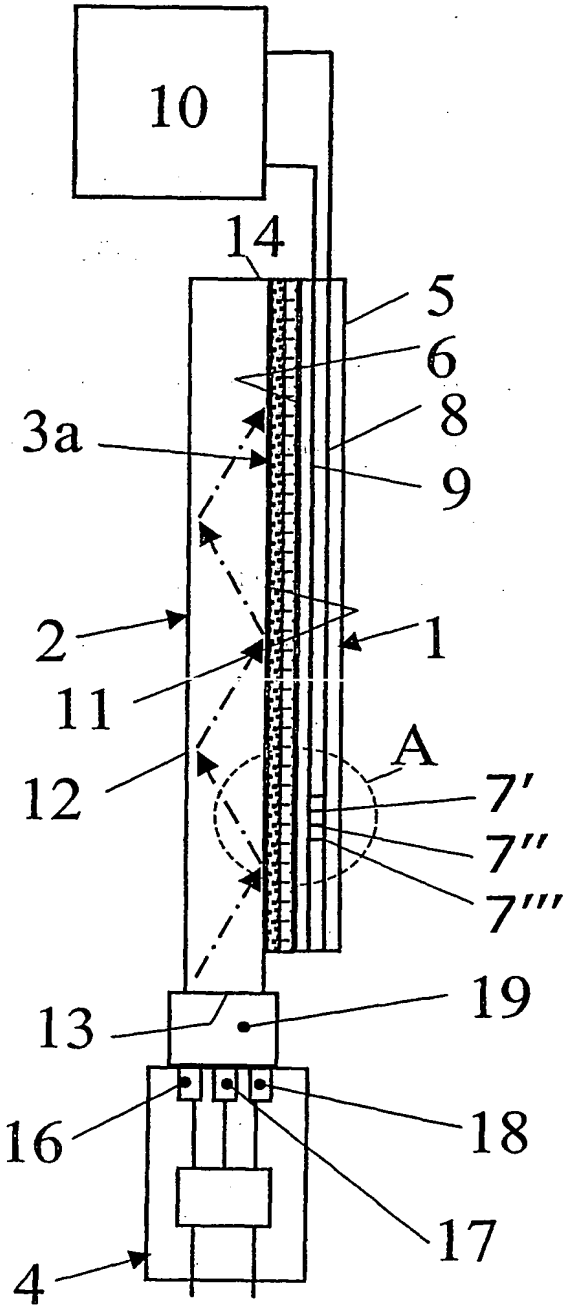

Fig.1

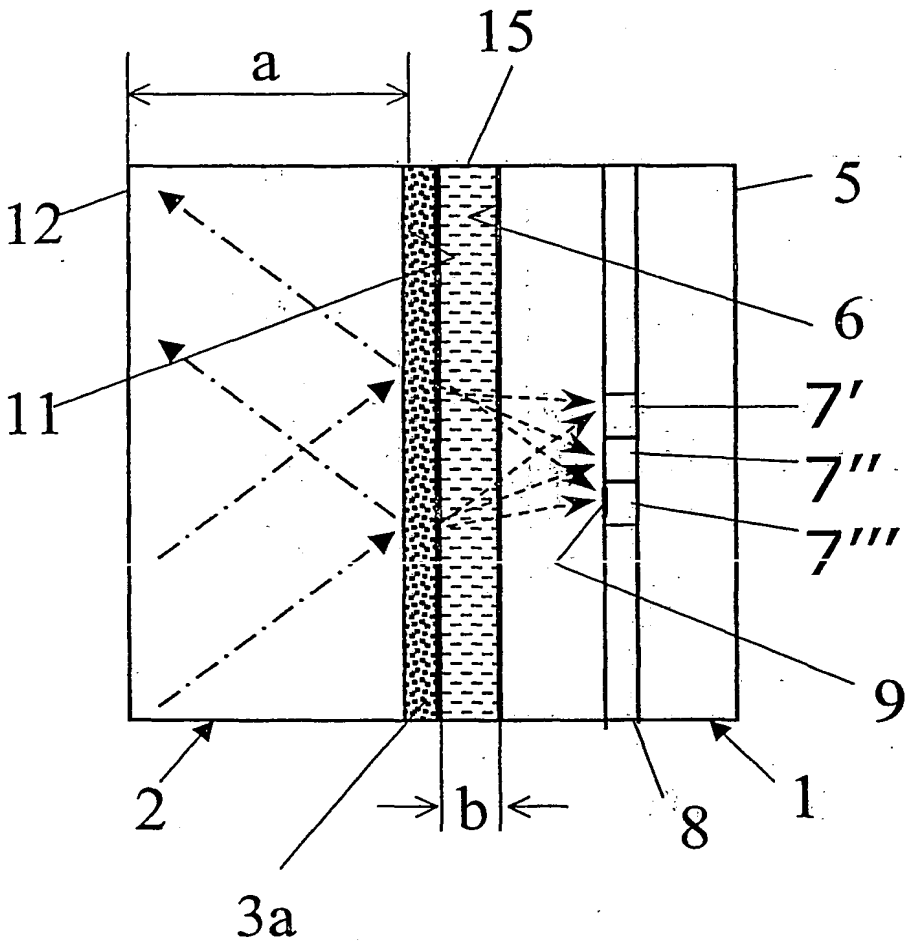

Fig.2

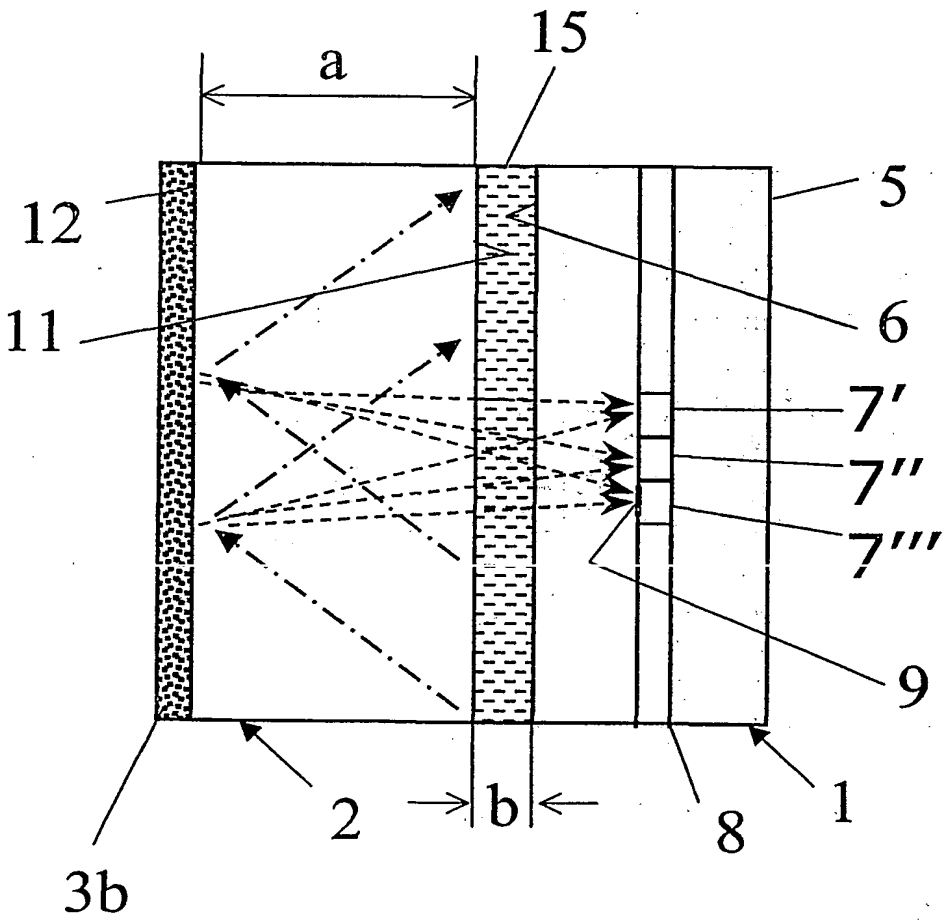

Fig.3

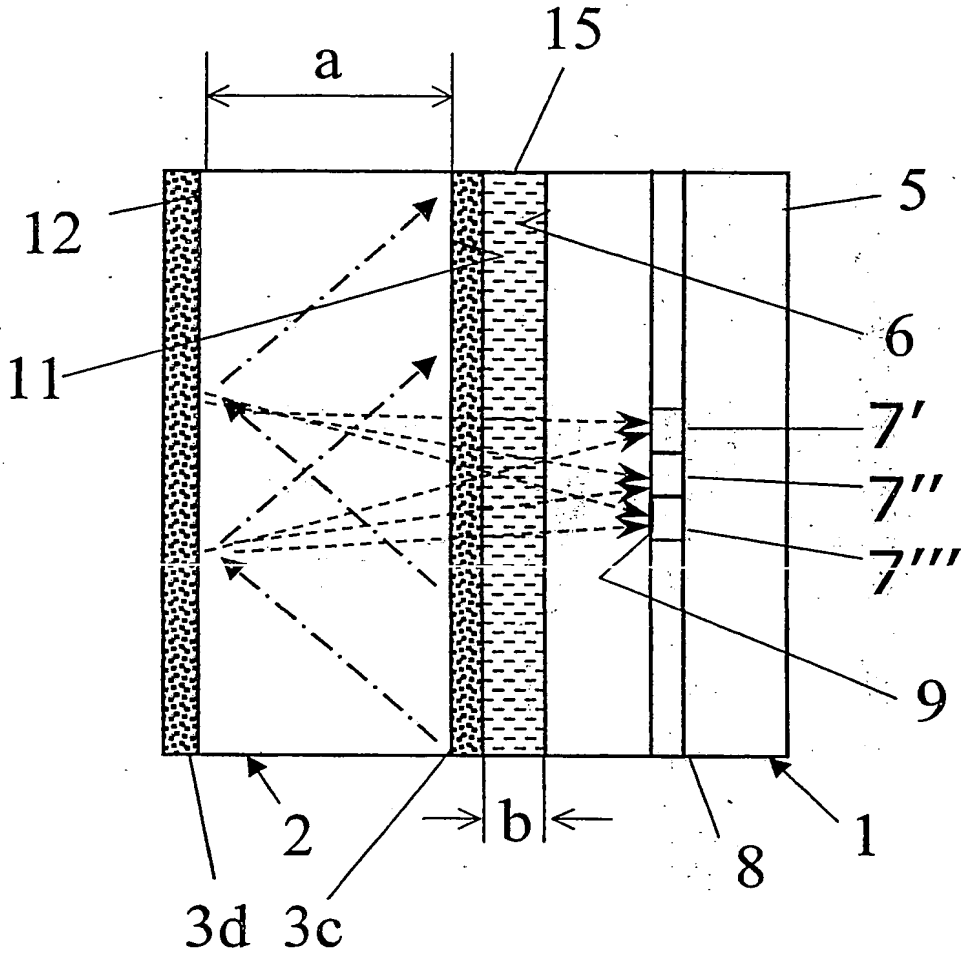

Fig.4

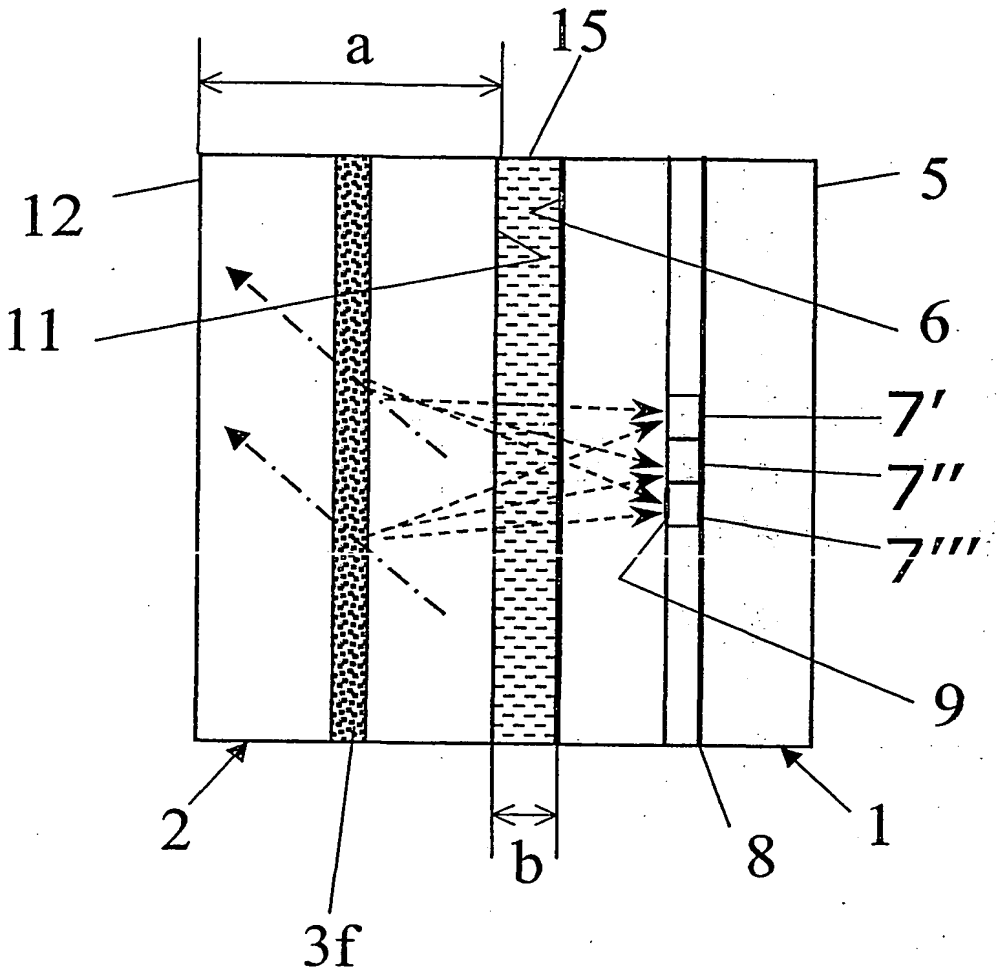

Fig.5

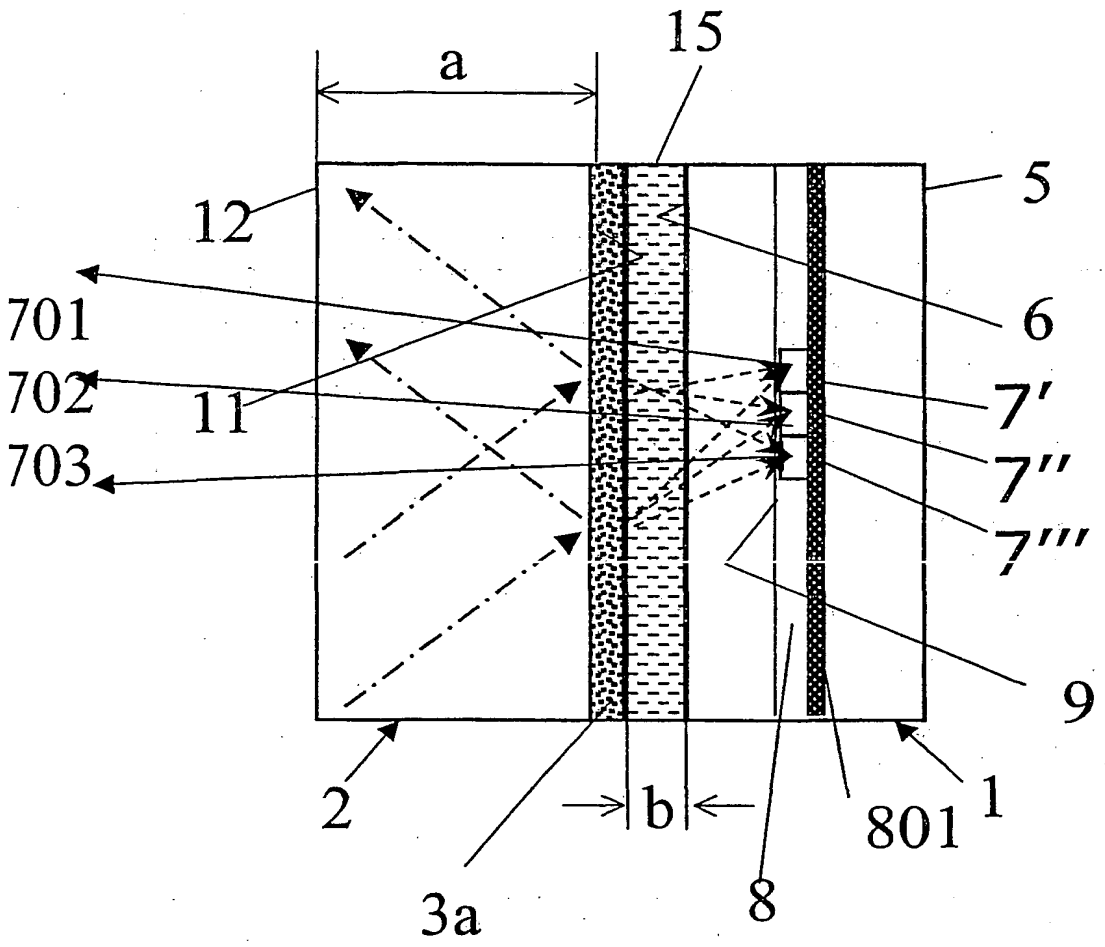

Fig.6

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/13357 G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, PAJ, IBM-TDB, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5 889 567 A (GALE RONALD P ET AL) 30 March 1999 (1999-03-30) column 19, line 22 - line 60; figure 23	1-3, 8-10, 12-14
A	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 02, 30 January 1998 (1998-01-30) -& JP 09 265085 A (TOPPAN PRINTING CO LTD), 7 October 1997 (1997-10-07) abstract	1-3,6,8, 9,12,13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2001	28/11/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/41203

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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